PARALLEL VECTOR LOCK-IN THERMAL WAVE IR VIDEO IMAGING OF MICROCRACKS IN CU FOILS DEPOSITED ON POLYIMIDE

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INTRODUCTION

Recently, the concept of area-wide lock-in detection in infrared video imaging and its application to thermal wave imaging was demonstrated.[1] This technique combines the lock-in detection method with an IR video camera and almost real-time digital image processing to form a parallel vector lock-in thermal wave IR video imaging system. In this method each pixel of an image is processed in the manner similar to the lock-in detection method while the sample is excited (heated) synchronously with a square-wave modulated joule heating. The synchronous detection allows the non-synchronous background radiation to be subtracted from the signal resulting in an enhanced signal-to-noise ratio, thus allowing the signal of interest to be measured even in situations where it is completely masked by noise. The advantage of IR detection (8-12 μm) and high speed data acquisition combined with the area-wide lock-in detection makes this a unique thermal wave imaging technique for non-destructive evaluation. In this paper we report the application of this lock-in thermal wave IR video imaging technique using ac Joule heating to the imaging of microcracks in Cu foils deposited on polyimide substrates. Comparison of the lock-in video images of good and faulty samples are presented.

EXPERIMENTAL TECHNIOUE

Figure 1 shows a block diagram of the experimental set-up. A conventional IR video camera is used to detect the infrared radiation from the sample. The signal from the camera is processed by a video signal processor which is controlled by a color work station. The sample under investigation is stimulated by ac Joule heating whose frequency is set by the work station using the heating control electronics. The data is acquired synchronously with the heating cycle. The timing control assures the synchronization between the heat source and the lock-in analysis. The heating frequency can be varied from sub-Hz to 2KHz, where, the upper limit is set by the speed of the IR camera. The video signal processing involves digitization of the incoming analog signal at 10 MHz and then digital multiplication of the video signal with the sine and cosine functions of the phase. The data are accumulated in separate buffers (each 512 x 512 x 16 bits) and after the averaging, displayed as in-phase and quadrature images, similar to the signal processing of a lock-in amplifier. The subtraction and averaging is necessary in order to eliminate the background noise and obtain a good signal-to-noise ratio. Increasing the number of cycles of averaging decreases the background noise but keeps the magnitude of the modulated signal the same. The number of averaging cycles plays the same role as the time constant in the conventional

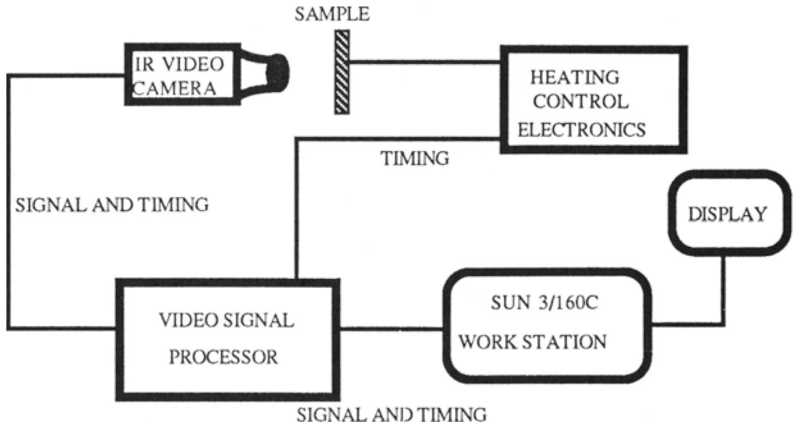

Figure 1. A block diagram of the experimental set-up.

lock-in amplifier.[1] The color work station is used display the image using a WSU developed custom colormapping system. A C-language software utilizing all the facilities of the Sun 3/160C color work station's window system creates the colormap which gives the best visual effect. The image display can be further enhanced by first plotting a histogram of the pixel values and then using the histogram to equalize the color map. In this method, an enhanced image display can be obtained without actually affecting the data.

RESULTS AND DISCUSSION

The samples used in this study are copper film microbridge (a few microns thick) on a polymer substrate, covered by a thin (almost 10μm) film of kapton.[2] A schematic diagram of the sample is shown in Figure 2. An ac current sent through the sample provides localized joule heating of the microbridge. A 3X telescopic lens with a 2.5 inches close-up attachment was used with the IR camera optics to obtain an expanded view of the image area. The experiment involved obtaining lock-in images of the microbridge at several frequencies. Typically, 500-700 milliamperes of current was used to stimulate the sample. The frequency of heating is set by the work station via the red signal of the Data Cube image processing system and using the WSU designed heating control electronics.

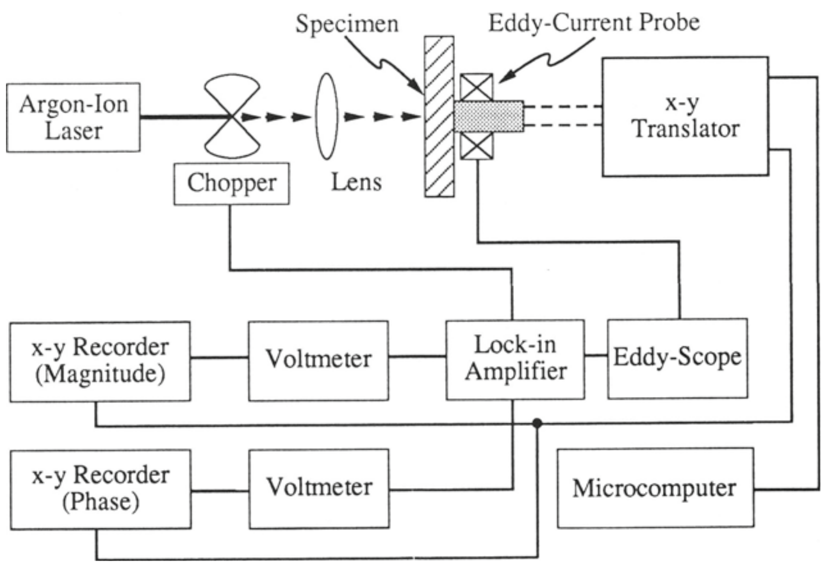

Figure 2. A schematic diagram of the sample showing the microbridge.

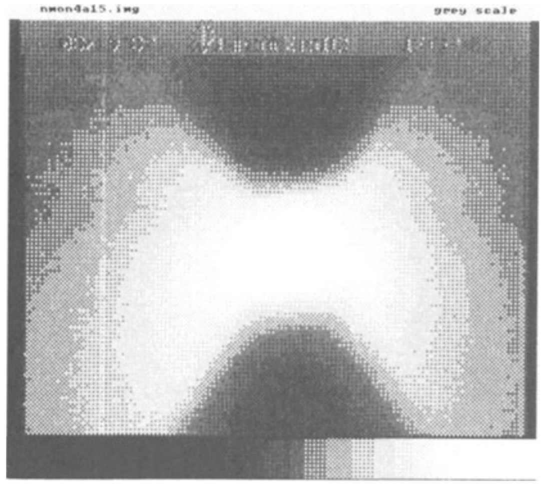

Figure 3. In-phase lock-in video image of a good sample at 15Hz

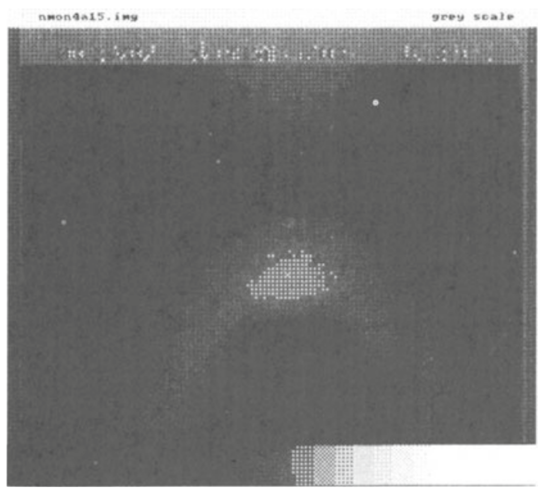

Figure 4. Quadrature lock-in video image of a good sample at 15Hz

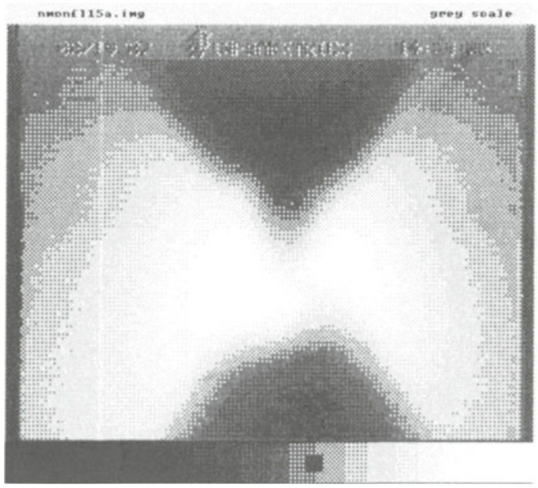

Figure 5. In-phase lock-in video image of a faulty sample at 15Hz

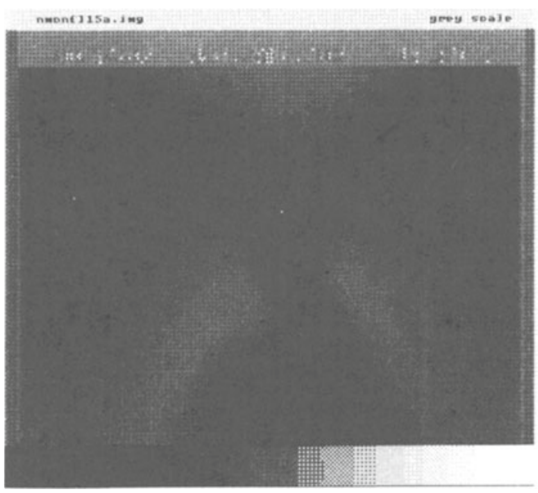

Figure 6. Quadrature lock-in video image of a faulty sample at 15Hz

After a preassigned number of frame-averaging, the in-phase and quadrature lock-in images accumulated in the buffers are transferred to the Sun work station and displayed using the image display software. In this method we have studied several copper film microbridge samples at several different frequencies from 15 Hz to 1KHz. The purpose of the study was to determine whether this new technique of lock-in thermal wave imaging can be used to detect defects in this kind of samples. Figures 3 and 4 respectively shows the in-phase and quadrature lock-in video image of a good copper foil sample at a modulation frequency of 15 Hz. The heat is generated predominantly in the microbridge and since the sample did not have any flaw the heat flow was continuous. The in-phase and quadrature lock-in video images of a faulty sample at the same modulation frequency (15 Hz) and at the same average power are shown in Figures 5 and 6 respectively. In this case due to the presence of a microcrack in the bridge the heat flow is interrupted and the images are quite different than those in Figures 3 and 4. It should be pointed out here that since copper is a very poor emitter in the 8-12 μm spectral range, all the images were taken through the kapton side of the sample since, the kapton is a much better IR emitter than copper.

CONCLUSION

In this work we have described a parallel lock-in thermal wave IR video imaging system and applied it to image microcracks in Cu foils deposited on polyimide. The significance of the lock-in video imaging technique is that contrary to conventional video imaging technique[3], this method retains the phase information of the thermal wave, which has been proved to be very useful in several thermal wave imaging method.[4,5] The lock-in IR video imaging technique provides a useful tool to researchers in non-destructive evaluation.

ACKNOWLEDGEMENT

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